THE MULTICHANNEL ASTROMETRIC PHOTOMETER WITH SPECTROGRAPH: A NEW INSTRUMENT FOR THE CHARACTERIZATION OF EXTRASOLAR PLANETARY SYSTEMS

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With few exceptions, the recently detected extrasolar planetary systems are of a totally unexpected nature, and hence give rise to questions about current theories of planetary evolution and formation. To better address these questions, and to eventually better understand our own solar system, more detailed study of these systems is needed. One instrument with the ability to detect planets of Uranian mass, and hence the ability to better characterize known extrasolar planetary systems, has already been awarded observing time on the Keck telescope. That instrument, the Multichannel Astrometric Photometer with Spectrograph (MAPS), is unique in many ways, and has attributes that give it distinct advantages in a long term observing program. It is the only instrument to simultaneously use two detection techniques (radial velocity and astrometric methods are used). It also makes use of very small field relative astrometry, and the simultaneous measurement of its objects in two colors to substantially improve the astrometric precision attained. The MAPS spectrograph also has resolving power sufficient to discern the shapes of stellar absorption lines, which is important in avoiding false planet detections due to magnetic activity cycles.

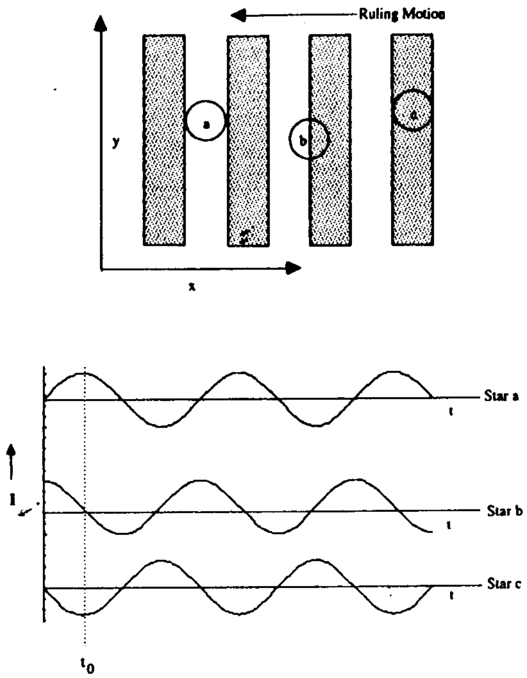
The MAPS is essentially an improvement on an existing instrument, the MAP, which has been in operation at the Allegheny Observatory since 1986 (for a detailed description of the MAP, see Gatewood, 1987). Both the MAP and MAPS pass their starlight through a moving Ronchi ruling situated at the focal plane. The modulated stellar signal is then transferred by fiber optic pickups to a detector, which is, in the case of the MAPS, an avalanche photodiode. Positional information is extracted from the difference in the phase of the different stellar signals. (Fig 1, after Stein 1979) This method allows for much more precise relative positions to be obtained than the older method of measuring photographic plates, as the ruling allows for multiple measurements of position with each observing run. The major innovations of the MAPS over the MAP are that the MAPS has a spectrographic feed, takes astrometric measurements simultaneously in two colors, and observes a very small field.

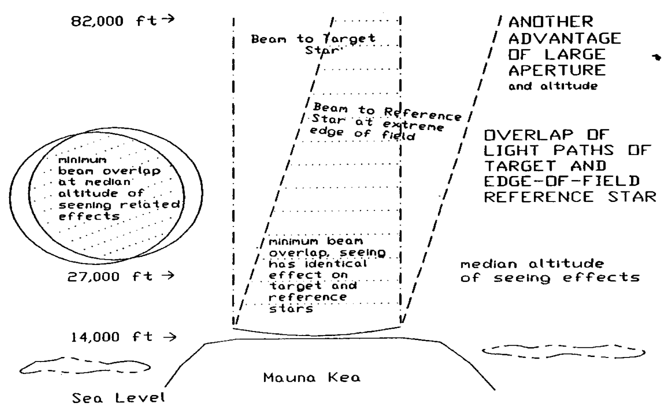
There are currently no other extrasolar planet detection programs that utilize more than one detection technique. The MAPS makes use of radial velocity techniques in the form of a spectrograph that can measure variations in the radial velocity of the target stars to precisions of 3 m/s. However, the major advantage of the MAPS spectrograph over those used in other radial velocity programs is its high resolving power (R = 300,000). This high resolving power is due to the fact that the MAPS spectrograph, due to the requirements of the astrometric portion of the instrument, observes bright stars with a large aperture telescope for much longer than other radial velocity instruments. The increased resolving power allows the shapes of stellar absorption lines to be determined as well as their velocity, and hence allows line changes due to magnetic cycling ("sunspot cycles") to be distinguished from true planet detections. In addition, the astrometric precision of the MAPS is 0.0001 arcsec/night, an order of magnitude better than the only other ground based astrometric detection program. By simultaneously using both techniques, we automatically increase the search space, possibly provide a simultaneous confirmation of detections, and expand the amount information obtained. This extra information will be useful in deciphering the complex signal produced by a multiple member planetary system.

The increase in the astrometric accuracy of the MAPS is due to two improvements to the original MAP system: the MAPS simultaneously observes in two colors (400 nm to 650 nm and 650 nm to 1000 nm), and it makes measurements in a very small field (4 square arcminutes) with a large aperture. Observing in two colors allows for explicit removal of the differentially refractive character of the atmosphere. Without such removal, the relative positions of red and blue stars can change by up to tens of times the sought precision over the course of an observation. Observing in small fields has also been shown to dramatically increase astrometric precision (Han & Gatewood, 1995). The beams of stars in a small field overlap through much of their journey through the atmosphere, (Fig 2, after Hale 1995) and hence, any atmospheric effects are experienced by both objects. This area of overlap also increases with aperture, and hence, by observing a small field with a large telescope like the Keck, one achieves the highest precision possible from the ground.

References: Gatewood, G.D. (1987) *Astronomical Journal* **94**, 213. Hale, A.S (1995) *Bulletin of the American Astronomical Society* **27**, 32.01. Han, I. and Gatewood, G.D. (1995) *Publications of the Astronomical Society of the Pacific* **107**, 399. Stein, J. (1979) Ph.D. dissertation.

Fig 1
Stellar Signals Modulated by a Ronchi Ruling





An illustration of how smaller fields of view yield more accurate astrometric results.

Fig 2